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GCSE AQA Physics Topic 6

6. Waves

6.1 Waves in Air, Fluids, and Solids

6.1.1 Transverse and Longitudinal Waves

- **Transverse waves:** Waves where the oscillations are perpendicular to the direction of the wave's travel.
 - Example: Ripples on a water surface.
- **Longitudinal waves:** Waves where the oscillations are parallel to the direction of the wave's travel.
 - Example: Sound waves travelling through the air, showing areas of compression and rarefaction.

The wave speed equation

$$v=f \times \lambda$$

Where:

- **v** = wave speed (m/s)
- **f** = frequency (Hz)
- **λ (lambda)** = wavelength (m)

6.1.2 Properties of Waves

- **Amplitude:** The maximum displacement of a point on a wave from its undisturbed position.
- **Wavelength:** The distance from a point on one wave to the equivalent point on the adjacent wave.
- **Frequency:** The number of waves passing a point each second.
 - **Equation:** $T = \frac{1}{f}$
Where T is the Time Period (s) and f is the frequency (Hz).

Wave Speed

- The speed at which the energy is transferred (or the wave moves) through the medium.
 - **Equation:** $v = f \times \lambda$
Where v is the Wave Speed (m/s), f is the Frequency (Hz), and λ is the Wavelength (m).

6.1.3 Reflection of Waves

- Waves can be reflected at the boundary between two different materials.
- Waves can be absorbed or transmitted at the boundary between two different materials.

6.1.4 Sound Waves

- Sound waves can travel through solids, causing vibrations in the solid.
- Within the ear, sound waves cause the eardrum and other parts to vibrate, which causes the sensation of sound:
 - **Outer Ear:**
 - **Pinna:** Collects sound waves.
 - **Ear Canal:** Directs sound to the eardrum.
 - **Eardrum:**
 - Vibrates when sound waves hit it.
 - **Middle Ear:**
 - Contains **Ossicles** (malleus, incus, stapes) that amplify vibrations.
 - **Stapes** connect to the **Oval Window**.
 - **Inner Ear:**
 - Contains the **Cochlea**, filled with fluid.
 - Fluid waves stimulate **Hair Cells** that convert vibrations into electrical signals.
 - **Auditory Nerve:**
 - Carries electrical signals to the brain.
 - **Brain:**
 - Interprets signals as sound (pitch and loudness).
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 - The conversion of sound waves to vibrations works over a limited frequency range, which restricts human hearing.
 - **Range of normal human hearing:** 20 Hz to 20 kHz.

6.1.5 Waves for Detection and Exploration

- **Ultrasound waves:** Have a frequency higher than the upper limit of human hearing.
 - Partially reflected when meeting a boundary between two different media.
 - The time taken for reflections to reach a detector helps determine the distance to the boundary.
 - Used for medical and industrial imaging.

- **Seismic waves:** Produced by earthquakes.
 - **P-waves:** Longitudinal seismic waves that travel at different speeds through solids and liquids.
 - **S-waves:** Transverse seismic waves that cannot travel through liquids.
 - P-waves and S-waves provide evidence for the structure and size of the Earth's core.
- **Echo sounding:** Uses high-frequency sound waves to detect objects in deep water and measure water depth.

6.2 Electromagnetic Waves

6.2.1 Types of Electromagnetic Waves

- Electromagnetic waves are transverse waves that transfer energy from the source to an absorber.
- They form a continuous spectrum, and all electromagnetic waves travel at the same velocity through a vacuum (space) or air.
- The electromagnetic spectrum is grouped by wavelength and frequency.
- Our eyes only detect visible light, which is a limited range of electromagnetic waves.

6.2.2 Properties of Electromagnetic Waves

- **Radio waves:** Produced by oscillations in electrical circuits.
 - Can induce oscillations in an electrical circuit when absorbed.
- **Gamma rays:** Originate from changes in the nucleus of an atom.
- **Ultraviolet waves, X-rays, and gamma rays:** Can have hazardous effects on human body tissue depending on radiation type and dose.
 - **Radiation dose:** Measured in sieverts, indicates the risk of harm from exposure.
 - Ultraviolet waves can cause skin ageing and increase skin cancer risk.
 - X-rays and gamma rays can cause gene mutation and cancer.

6.2.3 Uses and Applications of Electromagnetic Waves

- **Radio waves:** Used in television and radio.
- **Microwaves:** Used in satellite communications and cooking food.
- **Infrared:** Used in electrical heaters, cooking food, and infrared cameras.
- **Visible light:** Used in fibre optic communications.
- **Ultraviolet:** Used in energy-efficient lamps and sun tanning.
- **X-rays and gamma rays:** Used in medical imaging and treatments.

6.2.4 Measuring Velocity in Waves

1. Measuring Velocity in Water Waves:

- **Water wave velocity** can be measured using a ripple tank (a shallow tank of water with wave-generating paddles).
 - **Step-by-step process:**
 1. Set up a **ripple tank** and create waves on the surface using a **vibrating motor** or **wave generator**.
 2. Measure the **wavelength** (λ) by using a ruler to observe the distance between two consecutive peaks.
 3. Determine the **frequency** (f) by counting the number of waves passing a point in one second (use a stopwatch for accuracy).
 4. Calculate the **wave speed** using the formula.

2. Measuring Velocity in Sound Waves:

- **Sound wave velocity** can be measured using an **echo method** or **microphones** connected to an **oscilloscope**.
 - **Echo method:**
 1. Stand a known distance away from a reflective surface (e.g., a large wall or cliff).
 2. Clap your hands and measure the time it takes for the echo to return.
 3. Use the formula: $v = \frac{2d}{t}$

Where:

 - v = speed of sound (m/s),
 - d = distance to the reflective surface (m),
 - t = time for the echo to return (s).
 - **Microphone method:**
 1. Set up two microphones at a known distance apart.
 2. Emit a sound pulse (e.g., a clap) and measure the time it takes for the sound to reach both microphones using an **oscilloscope**.
 3. Calculate the speed of sound using

6.2.5 Absorption of Waves

Absorption refers to how materials take in energy from waves that pass through or strike them. Different materials absorb waves to varying degrees, depending on the **type of wave** and the **properties of the material**.

1. Absorption of Electromagnetic Waves:

- **Visible light:** Darker surfaces absorb more light energy and appear hotter compared to lighter surfaces, which reflect more light.
- **Infrared radiation:** This form of electromagnetic wave is absorbed well by **dark, rough surfaces** and reflected by **light, shiny surfaces**. This is why thermal insulation often uses shiny materials to reflect infrared radiation back into a building.

- **Applications of infrared absorption:**
 - **Infrared cameras** detect heat by observing the absorption and emission of infrared radiation.
 - **Greenhouses** trap heat as infrared radiation is absorbed by the glass or plastic, warming the air inside.

2. Absorption of Sound Waves:

- **Sound absorption** occurs when materials convert sound wave energy into other forms, usually heat.
 - **Soft materials** (like foam, carpets, or curtains) absorb sound waves more effectively than hard materials (like concrete or metal). This is why recording studios use soundproofing materials that absorb sound to reduce echoes and noise.
 - **Acoustic absorption:**
 - When sound waves hit a material, they cause the molecules in the material to vibrate, converting some of the sound energy into heat energy.
 - **Soundproofing** materials work by increasing the absorption of sound waves and reducing their transmission through walls.

3. Absorption in Water and Other Media:

- Waves, such as **light** or **sound**, are absorbed by water and other dense media more efficiently than by air or other less dense materials.
 - **Sound waves:** In water, high-frequency sound waves are absorbed more than low-frequency sound waves, which can travel further (used in sonar technology).
 - **Light waves:** Water absorbs **red light** more efficiently than blue light, which is why deep water often appears blue.

6.2.5 Lenses

- **Lens function:** Forms an image by refracting light.
 - **Convex lens:** Brings parallel rays of light to a focus at the principal focus.
 - **Focal length:** The distance from the lens to the principal focus.
 - **Concave lens:** The image produced is always virtual.
- **Ray diagrams:** Show the formation of images by convex and concave lenses.
- **Magnification:**
 - **Equation:** $\text{Magnification} = \frac{\text{Image height}}{\text{Object}}$
 - Magnification is a ratio and has no units.

6.2.6 Visible Light

- Each colour within the visible light spectrum has its own wavelength and frequency.
- **Specular reflection:** Reflection from a smooth surface in a single direction.
- **Diffuse reflection:** Reflection from a rough surface causing scattering.
- **Colour filters:** Absorb certain wavelengths and transmit others.
 - The colour of an opaque object is determined by which wavelengths are reflected and which are absorbed.
 - If all wavelengths are reflected equally, the object appears white. If all are absorbed, it appears black.
- Objects that transmit light are either transparent or translucent.

6.3 Black Body Radiation

6.3.1 Emission and Absorption of Infrared Radiation

- All bodies emit and absorb infrared radiation, regardless of temperature.
- The hotter the body, the more infrared radiation it emits in a given time.
- A **perfect black body** absorbs all incident radiation and does not reflect or transmit any radiation.
 - A good absorber is also a good emitter.

6.3.2 Perfect Black Bodies and Radiation

- A body at a constant temperature absorbs radiation at the same rate it emits radiation.
- The temperature of a body increases when it absorbs radiation faster than it emits.
- **Factors affecting Earth's temperature:** Rates of absorption and emission of radiation, and reflection of radiation into space.